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POTENTIAL APPLICATIONS OF RADIOISOTOPES IN THE NAVY

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POTENTIAL APPLICATIONS OF RADIOISOTOPES IN THE NAVY

Technical Report R-445

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by

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ABSTRACT

The Naval Civil Engineering Laboratory has conducted a study of the potential applications of isotopic devices and techniques within the Naval Shore Establishment. Radiation characteristics, general applications of isotopic devices, and specific problem areas are discussed. Recommendations are included for the use of surface density and moisture gages in the inspection of compacted earth, and for additional work in the determination of the thickness of in-place steel sheet piling and the thickness and density of concrete.

The Laboratory invites comment on this report, particularly on the results obtained by those who have applied the information

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INTRODUCTION

Since the advent of the atomic era, a great number of methods and devices have been developed which are based on techniques employing radioisotopes. The proper application of these techniques has provided industry with many useful tools for improving production. The Naval Shore Establishment is in itself a collection of individual industries, so the techniques used by civilian industry should be equally applicable within the military counterpart. Because of this probable applicability, the Naval Civil Engineering Laboratory (NCEL) was asked to investigate isotopic methods and devices to determine whether (and how) they could be used within the Naval Shore Establishment. This report summarizes the efforts undertaken in this study and makes specific recommendations for further work in the investigation of isotopic devices.

Properties and Characteristics of Nuclear Radiations

The NCEL studies were conducted with alpha, beta, gamma, and neutron radiations. The first two are charged particles and the second two are uncharged. The presence of the charge associated with beta particles means that it is difficult for the particle to penetrate matter and that the particle's range of penetration is comparatively short. The uncharged gamma rays, in contrast, have long penetration ranges in most materials — for instance, they penetrate several inches into lead and many feet into water and similar materials. On the other hand, beta particles penetrate only a few inches into water, and alpha rays only a few thousandths of an inch into water. The neutron is unique in that its behavior depends greatly on the amount of hydrogen present in the material it is penetrating. Collisions with hydrogen nuclei slow down energetic neutrons very rapidly until they have only thermal energies. Such slow neutrons are readily captured by most of the neighboring nuclei, whereas fast neutrons are not easily absorbed in this way. For instance, neutrons may penetrate a few feet into lead or many feet into dry rock or sand, but a comparatively short distance into water, wood, or other hydrogenous materials.

Beta and gamma rays are affected primarily by the electron clouds surrounding the atoms and molecules which make up the material that they are penetrating. The density of electrons in the material depends on the gross density of the material itself and its chemical composition; that is, atoms with high atomic numbers scatter gamma radiation and electrons more effectively than those with lower atomic numbers. The same is true of alpha particles, but because of their large mass and high charge, their penetration is so small as to be of little concern in this report.

Radiation, when it enters matter, may be either absorbed or scattered. Some of the applications discussed later in this report depend on the radiation being absorbed. In order to measure the absorption of radiation, it is necessary to have the radiation detector and source on opposite sides of the object being examined. This is the arrangement for the industrial devices which depend on absorption, such as thickness gages and level indicators. The amount of absorption depends principally on the mass of material between the source of the radiation and the detector, the effects of chemical composition being relatively minor in this case.

Scattering, on the other hand, means that the direction of the particle is changed on collision with an electron in the material, but that the particle is not lost. Scattering may occur several times in the life of the particle, and may, in fact, completely reverse the direction of the particle. Instruments which depend on backscattering use this phenomenon in their operation. A particle, ejected from a source, enters the test object, is scattered many times and then emerges to enter the detector. Some particles are not scattered back to the detector, of course, and are lost. The ratio of the number of particles detected to the number emitted by the source is dependent on the mass and composition of the material being investigated. Since in measuring backscatter the source of radiation and the detector are on the same side of the material, they may be, and frequently are, incorporated into the same instrument. The phenomenon of backscattering is used with beta particles for small thicknesses, like thin coatings on metals, where the penetration is shallow; it is used with gamma rays where deeper penetration is desired, as in measuring the compaction of earth or concrete; and it is used with neutrons for measuring such things as the hydrogen content of various materials, asphalt pavements for uniformity, and the moisture content in soil.

Problem Areas and General Solutions

The applications of beta and gamma radiation are quite similar, the main difference being in the range of penetration desired. However, secondary differences concern how the type of material in contact with the radiation affects the measurements of the absorbed or scattered particles. Beta and gamma radiation may be detected either before or after scattering. Detection of the direct beam of radiation from a source enables one to place the source in locations inaccessible by other means.

For example, a beta-ray source can be pushed through an exposed pipeline as part of a leak test. If the proper isotope is selected in the source, the normal thickness of the pipe wall will absorb all the radiation. However, even a pinpoint hole in the pipe wall will allow some beta radiation to penetrate the wall. A detector can locate this radiation and thus pinpoint the leak. The application of beta rays to this type of measurement is limited to cases where the pipe is exposed and may be readily surveyed with a detector. Also, a buildup of corrosion product

might be mistaken for good metal by the detector, thus obscuring a potential leak. Actually, leaks in an exposed pipe are usually detected visually, and the only merit that can be claimed for the radioactive method is the location of unusual thinning of the pipe wall caused by corrosion or other influences. In a similar way, a more energetic source of beta rays may be used to penetrate the pipe wall so that the presence of internal deposits in the pipe can be detected. (These types of measurements can also be performed by ultrasonic techniques.)

In cases where the pipe is buried, a liquid gamma-ray source may be pumped through the pipe. If the pipe is punctured, the source material will leak out and, after the pipe is flushed, the location of the radioactivity which leaked out may be found, thereby localizing the leak. This type of measurement does not necessitate uncovering the pipe. These procedures require care to prevent contamination of the environment with excessive amounts of radioactivity. There are, however, limited amounts of radioactivity which are permitted for such measurements even though such amounts may ultimately be absorbed in the ground or air.

Backscatter radiation may be used to determine the condition of sheet metal, such as is used for certain kinds of piling. Here, if a source of either beta or gamma rays is brought near a substance, the material will reflect and scatter the incident radiation. The reflected radiation in turn may be detected. The intensity of the reflected radiation depends on several quantities, among which are the amount of material present and its effective atomic weight. If all other conditions of the experiment are kept the same and the apparatus is moved over the material (as when the source-detector combination is moved over a sheet of metal), the uniformity of the composition of the material may be determined. It is possible to convert such relative measurements into absolute measurements by calibrating the detecting instrument.

Neutron radiation may be used to determine moisture content (that is, hydrogen content). The presence of hydrogen significantly decreases the energy of an incident energetic beam of neutrons. This decrease may be detected, and thus either relative or absolute amounts of moisture can be determined.

The preceding examples are not all-inclusive, but serve rather to indicate the areas considered in NCEL's investigation. This report will be concerned with the program as originally formed, possible applications of isotopic methods and devices for field use or within NCEL's research and evaluation activities, and some preliminary testing.

PROGRAM

A relatively long-range program was formulated to determine the applicability in the Navy of isotopic methods and devices. Incorporated into the plans were a literature search, in-house interviews, a field survey, and field tests of selected isotopic methods and devices.

Literature Search

A continuing literature search was initiated to determine the extent of prior applications of radioisotopes. One early outgrowth of this search was the compilation of a 635-entry bibliography[1] that covered a wide range of subjects related to isotopes and their uses. Individual articles make up almost all of the entries; there are, however, 29 separate bibliographies included which reference many of the other articles.

Recent periodicals and indexes were checked for pertinent articles. As the scope of the task became more clearly defined, it was possible to restrict the search to those references having potential application to specific problems.

In-House Interviews

An early action of some significance was a survey of the existing NCEL program. The objective of this survey, conducted under contract, was to determine which projects might benefit from radioisotope applications. A two-man review team interviewed 24 members of NCEL's professional staff, and thereby covered a major part of the NCEL research and evaluation program. The review team sorted out problems amenable to solution by isotope techniques, cited pertinent literature references, and described methods for solving particular problems.[2] Subsequent to the contract review of NCEL's program, a number of repeat interviews were held by NCEL program personnel. As far as possible the staff members contacted during the earlier review were asked whether their problem still existed, either in the previous state or in a more clearly defined condition. Problems which continued to be of concern included the determination of the density and moisture content of soil and the thickness of snow packs, the detection of corrosion, and the investigation of moisture penetration.[3]

Field Survey

About 15 East Coast and West Coast Navy activities were visited in an attempt to learn from field personnel the problems which were of greatest concern to them. The net results of these visits are summarized in Table 1, which gives the frequency that each problem was mentioned. BuDocks Division Offices were visited, as were individual stations, so a single entry can represent either a local problem or one that may be fairly general over an entire naval district.

Field Tests

Several problems were selected for testing to determine both the practicality of solving them with presently available isotopic devices and the cost of using these devices as opposed to current procedures. Preliminary tests were conducted to determine the effect on degree of backscatter produced by (1) different thicknesses of steel, (2) proximity of the measuring device to an abrupt change in contour (as with steel sheet piling), and (3) surface roughness.

Table 1. Problems at Naval Activities

Problem	Frequency of Mention
Locating pipe leaks	11
Detecting slag and rust buildup	8
Inspecting roofs	8
Measuring soil density	6
Detecting corrosion	6
Determining paint thickness	5
Inspecting concrete	5
Determining creosote penetration and retention	4
Determining asphalt density	4
Controlling smoke	3
Inspecting welds	3
Determining moisture content of wood	3
Analyzing engine oil	2
Determining continuity of asphalt joints	1
Determining insecticide flow rate	1
Inspecting for marine borers	1
Tracing buried pipeline	1

POTENTIAL APPLICATIONS OF ISOTOPES

In-house interviews and conversations with field personnel uncovered an extensive group of problems; many techniques and devices which could be used in solving the problems were found through the literature search. The problems, mentioned briefly before, have been broken down into three groups and will be discussed on that basis. The section on primary field applications deals with those problems and applications of greatest interest to BuDocks and the various field activities. Other possible field applications are discussed in the section on secondary field applications. The possible uses of radioisotopes in NCEL programs are discussed in the section on research and evaluation applications.

Primary Field Applications

Locating Pipe Leaks. The most common problem, according to the field survey, is locating underground pipe leakage, regardless of whether the pipe is leaking water, petroleum products, or steam. Locating a pipe leak can be relatively easy, or it can be a time-consuming, fund-consuming problem. If the line develops a leak and the fluid makes an obvious trace (as a damp spot or a steam cloud) on the surface immediately above the leak, location is simple. This, however, is an uncommon occurrence. At one installation, where almost all the ground surface is blacktopped, the leak is indicated by a bulge in the pavement surface directly over the leak. Again, this is an isolated occurrence.

Generally, although traces of a leak will show on the surface at a particular location, the actual leak may be a considerable distance from the surface indication. As a result, excavation at the indicated spot often fails to uncover the leak, and further excavation must be done along the pipe until the actual leak is found. Another complication arises when the pipeline is under paving, such as a roadway or a concrete slab floor. The need for accurately locating the leak is especially obvious in these cases.

A leak in a buried pipe may be located in any of several ways by putting radioactive material into the pipe. One method, applicable when the pipe is not too deep, is first to block off both ends of the suspected section. Next, inject a known quantity of radioactive fluid into the pipe, and then allow the normal pipe fluid to flow under pressure through an auxiliary connection, if necessary. The radioactive fluid will move through the pipe until it gets to the leak. The movement of the fluid can be followed with a detector at the ground surface, and the leak located by an increase in the amount of radioactivity which will accumulate there.

A second method is to inject the radioactive fluid as before, this time allowing it to pass through the pipe under normal conditions so that it drains into a special reservoir. Some of the radioactivity will filter through the leak (or leaks) and can be detected from the surface after the line has been flushed.

When a great length of pipe is involved, both ends can be closed off and the solution containing the isotope injected at a central point, followed by the normal fluid under pressure. The direction taken by the isotope, as detected from the surface, will indicate the direction of the location of the leak. By closing off successive sections of the pipe, the leak can be located generally by a decrease in, or cessation of, movement of the isotope. The particular pipe section causing the change in movement of the isotope can then be checked to determine the location of the leak.

These methods are satisfactory regardless of the line fluid, the only requirement being that the solution containing the radioisotope be compatible with the line fluid. In other words, the solution should be miscible with the line fluid so that it fills the entire cross section of the pipe and does not separate from the line fluid by rising or settling.

If the existence of a leak is established by measuring a large decrease in total activity in an effluent stream, or if the pipe is buried too deeply and the location of the leaking fluid cannot be established from the surface, another method is suggested. After the line is flushed, a detector can be placed in the pipe and pushed along by a scraper, by fluid action on a damper vane placed on the detector, or by other means. The detector could transmit signals to a recording device outside the line and thereby indicate the level of activity along the pipe; an increase in activity would register at the location of the leak, which would be determined by the distance the detector had traveled.[2]

A method for differentiating between leaks in a pipeline and leaky cut-off valves is described in U. S. Patent 3,084,259.[4] This method utilizes several injections of a solution of radioisotopes at recorded intervals. By monitoring the passage of activity peaks, it is possible to determine whether the valve, the pipe, or both are leaking and to deduce the approximate locations of the leaks.

In attempting to locate leaks in a system filled with hydrocarbons (such as a gasoline or an oil line), one has the problem of obtaining a solution of the radioisotope which can be dispersed uniformly in the line fluid. A number of possibilities have been suggested in response to this problem. One of these, described in U. S. Patent 3,130,314,[5] involves the addition of an aqueous solution of sodium nitrate (tagged with the radioisotope sodium-24) to an emulsifier concentrate, followed by the addition of light naphtha. This particular mixture was used for monitoring a hot-pitch line and for obtaining other data, but it can be adapted to any hydrocarbon stream.

One requirement for all these methods for locating pipe leaks is the necessity of determining the initial amount of radio activity to be used and ensuring that it will present minimal hazards to personnel. Furthermore, there will be contaminated wastes, liquid and solid, for which storage facilities must be provided. The wastes must be stored until they have decayed to a level appropriate for disposal. Such problems can be minimized by selection of an isotope having a rather high energy and a short half-life.

Inspecting Steel Sheet Piling and Metal Roofs. The problem of detecting rust buildup caused by the corrosion of steel sheet piling and metal roofs is of much present concern in waterfront maintenance, as indicated in Table 1. If roof panels are properly sealed, there is little opportunity for moisture to creep in and initiate rust formation. With age, however, even a good seal may fail, and then the rusting begins. Such corrosion, however, is generally not noted until the material has failed. The determination of the amount of remaining metal is important in the inspection of steel sheet piling since the residual metal is a measure of life expectancy and serves as an aid in planning the replacement of the piling. Periodic examination with a suitable gage will reveal this rust buildup, and preventive action can be taken. The primary difficulty to be overcome in these problems is the development of a sufficiently portable device. In the literature examined, thickness gages discussed to any extent were designed for industrial applications. Some small devices were indicated, but were not fully identified. There appears to be room for development work in this field. Two devices have been advertised, one nuclear and the other operating on ultrasonic principles. These devices could be compared, the results to serve as a basis for the development of a more suitable and effective device.

The thickness of the materials used in steel sheet piling and metal roofs can be measured by determining the attenuation of the radiation passing through them. Such a determination would require that the source of radiation and the detector be on opposite sides of the material. Although this might be possible (but not very useful) for a roof or wall, it is impractical for most installations of steel sheet piling, where only one side is accessible.

A more practical method is the use of a backscatter device, where the radiation impinging on one side of the panels of material will either go completely through or be scattered, some of the radiation emerging on the same side that it entered. With this arrangement, both source and detector are on the same side of the material and can be combined into a single instrument.

This backscattering principle, requiring access to only one side of the material being investigated, has been used with all three types of nuclear radiations mentioned above (beta rays, gamma rays, and neutrons). Because of differences in the scattering mechanisms for the three types of radiations, the interpretation of measurement will depend on the type used.

The scattering of beta and gamma radiation is produced by the external electron system of the atoms making up the compounds in the test specimen. This makes it possible to distinguish changes in chemical composition in substances (for example, sheet metals with a coating of paint, plastic, or a different metal or alloy) or changes in density of the material, since the number of scattering electrons per unit volume is approximately proportional to the density. The penetration of the gamma rays through matter is considerably greater, generally, than beta rays, so that the applicability of the two types of radiation depends upon the problem at hand.

Measuring Density and Moisture Content of Soil. The ability to perform analyses of density implicit in the backscatter method has recently been greatly enhanced by developments in gamma-ray and x-ray technology.[6] It is possible, according to the referenced report, to distinguish objects containing gold from similarly appearing objects with no gold. By an appropriate selection of instrumental components, other metals can be distinguished. The limits of atomic numbers which will give a response are not known, but the region of application may be confined to the heavy elements.

On the other hand, the scattering of neutrons is quite independent of the electronic structure of matter and depends only on the nuclear properties, this being especially true of the mass of the nucleus and its ability to scatter or absorb the neutron in a collision. The hydrogen nucleus has particularly important scattering properties for neutrons, so that backscattering measurements are particularly sensitive to the amount of hydrogen present.

The basic principle in moisture determination is the detection of slow neutrons. Generally, a hole is bored into the earth and an instrument that includes a fast-neutron source and a slow-neutron detector is lowered into the hole, although topsoils may be measured by a surface probe, thus eliminating the necessity of digging a hole. The hydrogen content of the moisture present in the soil slows down part of the fast neutrons emitted by the source, a portion of the slowed neutrons are scattered back to the detector, and a corresponding signal is registered. This method is said to be valid for moisture contents from oven dry to saturated and requires a single calibration for soils free of organic matter.[7] With the bore prober, either wet or dry layers can be found if at least 1 inch thick, and two or more layers can be distinguished if separated by at least 4 inches; with the surface probe, a single top layer with an average thickness of about 4 inches can be measured.[8]

In-place measurements of the density and moisture content of soils and concrete are of great value to the construction industry. Such measurements would be particularly useful in evaluating the degree of compaction of soil at a construction site. The measuring device used for the soil measurements should also be applicable to measurements of the density of concrete in place. While the device could not be set up to evaluate the structural properties of concrete, it could be used to determine variations in the water - cement ratios which, when the cement and aggregate weights are known, can serve as an indication of strength variations that would result.[9] An instrument capable of measuring density would be expected to respond proportionally to the density. Whether such a device would be accurate enough for the delineation of very small changes in density, as might be needed for concrete, would best be determined by actual tests. Preiss has used the direct transmission of gamma rays through concrete for this purpose, as well as for locating voids or reinforcement steel.[10]

A fast (high-energy) neutron source in combination with a cadmium-covered boron trifluoride detector is said to yield measurements (by neutron scatter) independent of the chemical composition and the bulk density of the specimen, except for

the hydrogen content. The neutron scatter method for determining moisture content of soils can be used as a basis for developing a surface monitor, and such a device would thus be useful for measuring the water content of concretes.[11] Similar devices may also be used to survey the thickness of asphalt paving or its degree of compaction, or to monitor the initial mix of asphalt and aggregate.

For soil density measurements, a gamma-ray source and detector are used either on or below the surface. Rays emitted by the source are scattered by electrons in the soil. Since the electron density is proportional to the density of the soil, the gamma count in the detector is proportional to the density of the soil.

Devices for measuring the density and moisture content of the soil are used by several branches of the Federal Government, some branches of certain state governments, and a number of other organizations. A task force of the American Society of Civil Engineers has conducted a survey on the use of neutron meters in soil moisture measurement and has found a wide variety of uses for these devices.[12] The task force's report discusses neutron and gamma measurements, the necessary equipment (with descriptions of some available devices), advantages and disadvantages of using neutron meters for soil moisture measurements, and other problems related to the use of these meters. It also lists 81 references for those interested in further details.

An estimate of the savings to be made using surface density and moisture probes is given in Table 2.

Secondary Field Applications

Detecting Corrosion Products. Corrosion products are readily detected and identified by the use of radioisotopes, through the activation analysis technique. In this technique a sample is obtained of the carrier fluid that contains the various corrosion products. The sample is then made radioactive by placing it in a stream of neutrons. The gamma rays emitted by the radioactive sample are measured to determine the energy of the rays and the amount of radiation at each energy level. From these data it is possible to identify the elements present and their concentrations. The necessary data are obtained by multichannel gamma spectrometry and radiochemistry.

Corrosion products in engine lubricants may be used as a basis for determining the optimum time between engine maintenance periods. This time may be established by first inserting various radioactive materials into the engine. These materials should be so placed that they will be abraded by friction and the abraded particles will be carried away by lubricant fluids. These fluids are then sampled at various times and the amount of radioactivity quantitatively determined. The level of radioactivity per unit volume of lubricating fluid can be determined by comparison with the results of previous experimental calibrations. The amount of wear allowable for optimum maintenance can be determined. For example, in a piston-type engine the piston rings could be made radioactive. Similar techniques could be employed with other types of engines.

Table 2. Estimate of Savings Made Using Surface Density and Moisture Probes

Cost of nuclear probe	$6,300.00
Cost of inspector's time	$3.42/hour
Time for test with nuclear probe	2 minutes
Time for test by usual method (plus availability of laboratory)	20-30 minutes
Time saved per test	20 minutes
Value of time saved per test	$1.14/hour
Number of tests to equal cost of nuclear probe (6,300/1.14)	5,526
Time to perform tests (at 2 minutes/test; 30 tests/hour)	184.2 hours (4.6 + 40-hour weeks)
Time for nuclear probe to pay for itself (if used 25% of the time[a])	18.42 weeks (4.5 months)
Savings during first year	$10,000[b]

a/ Such extensive use is not typical of present or near-future construction schedules in the Navy. However in earth-dam or highway construction, an inspector might easily use density and moisture probes to this degree.

b/ There would probably not be sufficient usage to reach this figure.

Determining the Thickness and Density of Snow Packs. The thickness and density of snow packs may be determined in essentially the same manner as previously described for soil density determinations, and the same problems will be encountered. However, it is believed that the solution to these problems may be more easily achieved in the measurement of the density and thickness of snow than in the measurement of the density and moisture content of soil. This is because of the relatively small variations in the chemical composition of different types of snow as compared to the larger variations found in different types of soils.

Controlling Vehicular Traffic. Vehicular traffic may be controlled by placing sources of different energy gamma emitters on the side or bottom of the vehicle. As the vehicle passes a control point the various gamma energies are detected, the isotopes are identified, and the sequence in which the isotopes are placed is established. The isotopes may be arranged to form a code by which the vehicle's identification number is determined. The indicator, or readout, may be remote from the detecting mechanism. Such techniques are useful in the study of traffic patterns and security surveillance. They are being utilized by industry, and at least one U. S. Government patent is based on their application.

Investigating Moisture Penetration. Moisture penetration in various media may be studied by the use of tritiated water and liquid-scintillation counting techniques. These techniques might be useful in the study of the transmission of water through concrete, the penetration of water vapor through films, the leaking of water through ducts in tropical areas, and the penetration of moisture through brick, mortar, plaster, and around windows in air-conditioned rooms. Basically, moisture penetration may be determined by using tritiated water where the hydrogen atom is replaced by the isotope hydrogen-3. The two types of water mix perfectly; however, the tritiated water is radioactive, emitting a low-energy beta ray. This ray may be detected through the introduction of scintillation solutions in the liquid sample. The radioactive material causes the solutions to emit light if bombarded by radioactive particles. The light is detected by means of a photomultiplier tube. These various steps are incorporated in a liquid-scintillation counter. If the tritiated water mixture is injected at various points and samples are collected at other points, the migration of the water through the material under study may be determined. It is also possible to determine migration rate and whether the water is transmitted in the liquid or gaseous phase.

Research and Evaluation Applications

Accelerated Testing of Materials. Except for the wear and tear of the environment, organic materials deteriorate mainly by the mechanism of energy absorption. Under normal conditions this energy emanates from the ultraviolet components of sun radiation. However, equal damage occurs for equal energy

absorbed, regardless of the source of that energy. It is therefore a common test practice with organic materials to bombard them with energy from radioactive materials. Because of the high-energy gamma rays that are readily available, such as cobalt-60 and cesium-137 sources, life tests may be greatly accelerated utilizing these radiations in high intensities. There is no radioactivity created in the sample by such tests, allowing it to be freely handled in a materials testing laboratory. Energy absorbed in the test specimens may be determined from the nuclear parameters of the bombarding source and from the absorbed dose imparted to a gamma dosimeter.

Investigating Sand Migration. One of the programs at NCEL is concerned with the migration of sand under controlled and natural conditions. One method of investigating sand migration might include the use of sand coated with a radioactive material and then with sodium silicate, in much the same manner as some fallout simulants are prepared. The radioactive-coated sand could then be thoroughly mixed with normal sand (nonactive sand of the same generic type), placed in the bottom of a tank, and subjected to various waves and currents. At different times during the experiment, samples of sand could be obtained at various positions and subjected to radiometric analysis. Alternatively, the entire tank bottom could be scanned with a collimated gamma-ray detector, and a profile of the distribution of radioactive sand could be obtained. After some experience is gained in the laboratory, the experiments could be moved to the ocean front, where it would be possible to study the combined interaction of wind, waves, and currents on shore sand. The radioactivity utilized in this experiment must be adequate for a statistically significant radiometric measurement, but sufficiently low so that the experiment may be performed in an area open to the general public. Again, the same technique of sampling and radiometric analysis may be performed, with the exception, of course, that it would not be possible to scan the entire ocean floor over which the radioactive sand might be distributed. It would, however, be possible to survey selected areas by aid of a collimated detector mounted in a vehicle.

Investigating Migration of Salt Brine From Ice. The migration of salt brine from ice may be studied by tagging the ice with sodium-22, which is added to the sodium chloride present in the salt water. Thus, the salinity of the ice can be determined as a function of the depth of the ice after each successive freeze and thaw. After laboratory tests of the detection system and its calibration, it should be possible to develop techniques whereby a single gross radiometric analysis of an ice slab would determine the amount of fresh water in either liquid or solid form on top of the salt water. The calibration would be based upon the activity measurement of sodium-22 tagged salt water as a function of volume and thickness of the salt water.

Determining Distribution of Acid in Boiler Tubes. In order to determine the distribution of acid in boiler tubes during a cleaning process, one might use sulfuric acid tagged with sulfur-35 or hydrochloric acid tagged with chlorine-36.

The problem is to determine if the flow rate of the acids through the boiler tubes is uniform, one tube with respect to another. This may be accomplished by a small Geiger-Müller (GM) tube immersed in the cleaning fluids and placed just inside the exit end of the boiler tube. (The boiler tubes used are approximately 5/8 inch in diameter, and GM tubes may be commercially obtained as small as 1/8 inch in diameter.) The counting rate of each detector would be a function of the amount of radioactivity passing by in a unit of time. Thus, assuming a uniform mixture of the tagged solution, an equal counting rate between the various GM tubes would indicate a uniform flow rate. The radioactivity observed by each detector, and consequently the acid concentrations, associated with the various tubes should be noted under static conditions (no liquid flow) and a correction factor determined to adjust for slight variations in the various detectors' responses.

Determining Distribution of Air Bubbles in Condensation Systems. In determining the distribution of air bubbles in a condensation system, one might pass water which has been aerated with argon-41 tagged air or with pure argon-41 through the condensation system in a normal way. Subsequently, a gamma-ray-sensitive, collimated scintillation detector could be scanned over the system. Any bubbles would now contain argon-41. With little effort, the location of the bubbles could be determined through triangulation.

Evaluating Effectiveness of Cleaning Processes. The effectiveness of various cleaning processes may be evaluated by first coating parts to be cleaned with a radioactive material. The counting rate of these parts is then determined before and after cleaning, and the ratio between these rates is an indication of cleaning effectiveness. As one alternative, if the cleaning agent should have abrasive properties, the parts to be cleaned may be made radioactive, and the cleaning solutions can be checked for radioactivity before and after use.

Detecting Scale Deposition in Pipes. The early detection of scale deposition in pipes being used for evaporation or fluid flow is of interest to the Naval Shore Establishment. A research task concerned with this problem might include the use of fluids tagged with a radioactive material which, except for its radioactivity, is identical with the scale-forming agent. The amount of scale deposition on the inner surface of a pipe can readily be determined after the fluid flow is stopped. The fluid can be drained and the pipe washed, after which radiometric analysis can be performed by scanning the outside of the pipe with a collimated gamma-ray-sensitive detector. The observed radioactivity is directly related to the thickness of scale formation. Because of the capability of detecting small atom concentrations, extremely thin scale deposition may be quantitatively measured. (An ultrasonic device might also be considered for this application, if conditions of the test made its use feasible.)

Evaluating Filter Systems. There is a continuing need for determining the effectiveness of filter systems. Such systems frequently consist of a rough filter, a particulate filter, and a gas filter. There is also a need for a test kit to be used in the field by relatively unskilled personnel in the continual evaluation of filter effectiveness — that is, the lack of degradation of the filter package. One possible solution to this problem is to use an aerosol to spray particulate matter into the filter's ducted entrance and then to optically examine the various filters in order to determine the uniformity of filter action. A sampling nozzle may be placed before and after the filter, and a portion of the air stream may be sampled and adjusted for equal flow rate. The volume density of each sample may then be optically determined. The ratio between these densities would then indicate the effectiveness of the filtering action. The problem here is to determine if the spray of aerosol particulate material impinging upon the filter is impinging in a uniform manner over the entire surface of the filter. This question may be solved by using radioactive tagged particulate material and a grid of GM tubes placed in front of the air filter. An equal counting rate observed for each tube will then indicate a uniform flow of material into the filter system. A field test kit may be made from an aerosol bomb of particulate material graded from various sizes from 0.1 to 0.5 micron. A portion of these particles may be made radioactive simply by irradiating the entire aerosol bomb package. A suitable radioisotope, activated by such irradiation, is selected for analysis of filter action. The selection criteria are that its radiations are easily detectable and that its half-life is ralatively long so that irradiation may be accomplished before shipment to the field. The exact determination of which isotope to use must be based on the analysis of the elements desirable in the aerosol and thus must await further work. At this point the aerosol may be uniformly and totally expended into the filter system, after which various sections of the filter system can be removed and subjected to radiometric analysis. The output air from the filter can also be collected for radiometric analysis. A serial number on the can gives the amount of radioactivity in the can, date of determination, and isotope identification. From this information and the radiometric analysis of the filter, the effectiveness of each of the filter sections may be determined. The measurement equipment for this purpose most probably can be found at any naval installation as part of its disaster recovery equipment. However, if the equipment is not available for this application, commercially available equipment having a long life is available.

PRELIMINARY TESTS

Determining Condition of Steel Sheet Piling

A surface density probe (containing a 3-millicurie cesium-137 sealed source) was used to determine whether the backscatter method could be used to measure the thickness of steel sheet piling. Certain questions required answers: How sensitive

was the probe to changes in thickness? What effect would be produced by the probe's proximity to the edge of a pile face? What effect would result from the presence of air (or water) between the bottom of the probe and an irregular pile surface?

Four pieces of 0.075-inch-thick steel sheet were obtained for use in thickness measurements. The probe was placed on a flat sandy surface, and backscatter measurements were made. Then the steel plates were placed one by one between the probe and the sand until all four were in place. Backscatter measurements were made after each plate was added. Each set of measurements was averaged, and the result was plotted (in Figure 1) against the corresponding thickness of steel. A slightly rusted steel plate, 0.196 inch thick, was used in a similar manner and in combination with the 0.075-inch-thick sheets. The averages of each set of readings for this experiment are also shown in Figure 1. It is clearly shown that the probe is quite sensitive to changes in steel thickness and is accurate to ±0.01 inch for a total thickness of 0.2 to 0.5 inch.

Two narrow sheets of 0.075-inch-thick steel were stacked on two wider sheets. The probe was positioned in several locations across the plate to provide a variation in distance from the edge of the plate. The lengthwise centerline of the probe was used as the base from which distances to the edge of the plate were measured. A set of readings was taken in each location to determine the effect of the probe's proximity to an abrupt change in the contour. The average of each set of readings is shown in Figure 2, relative to the distance between the probe's centerline and the plate's edge. The readings are relatively uniform until the center of the probe is less than 2 inches from the edge of the plate; at that point the count rate increases rapidly. It is thus shown that the centerline of the probe may be as close to the edge of the pile face as 2 inches and still produce fairly reliable results.

A sheet of steel plate was obtained for use in determining the effect of air between the bottom of the probe and an irregular steel surface. The plate, a piece of decking, was smooth on one side; the other side had diamond-shaped nubs that were evenly distributed over the surface and that covered about one-third of the surface area. The plate was placed on a sand surface with the smooth side down. A standardization count was made, followed by a set of backscatter measurements. Then the plate was turned over, and the same measurements were made. By using the standardization value for Figure 1, it was possible to estimate the actual thickness of the plate. By measuring and weighing a portion of the plate, it was possible to determine its average thickness. The results of these calculations are shown in Table 3, along with measurements of the plate's actual thickness. These results indicate that backscatter measurements made on a smooth steel surface may compensate for any irregularities on the opposite surface, since the results are only 1.6% below the calculated average thickness. However, measurements made on a rough surface may indicate the presence of somewhat less metal than actually remains. This inaccurate measurement may be preferable from a planning standpoint.

Specimens of steel plate with varying concentrations and depths of pitting were not available; thus, the effects of pitting roughness (as opposed to protuberant roughness) could not be evaluated.

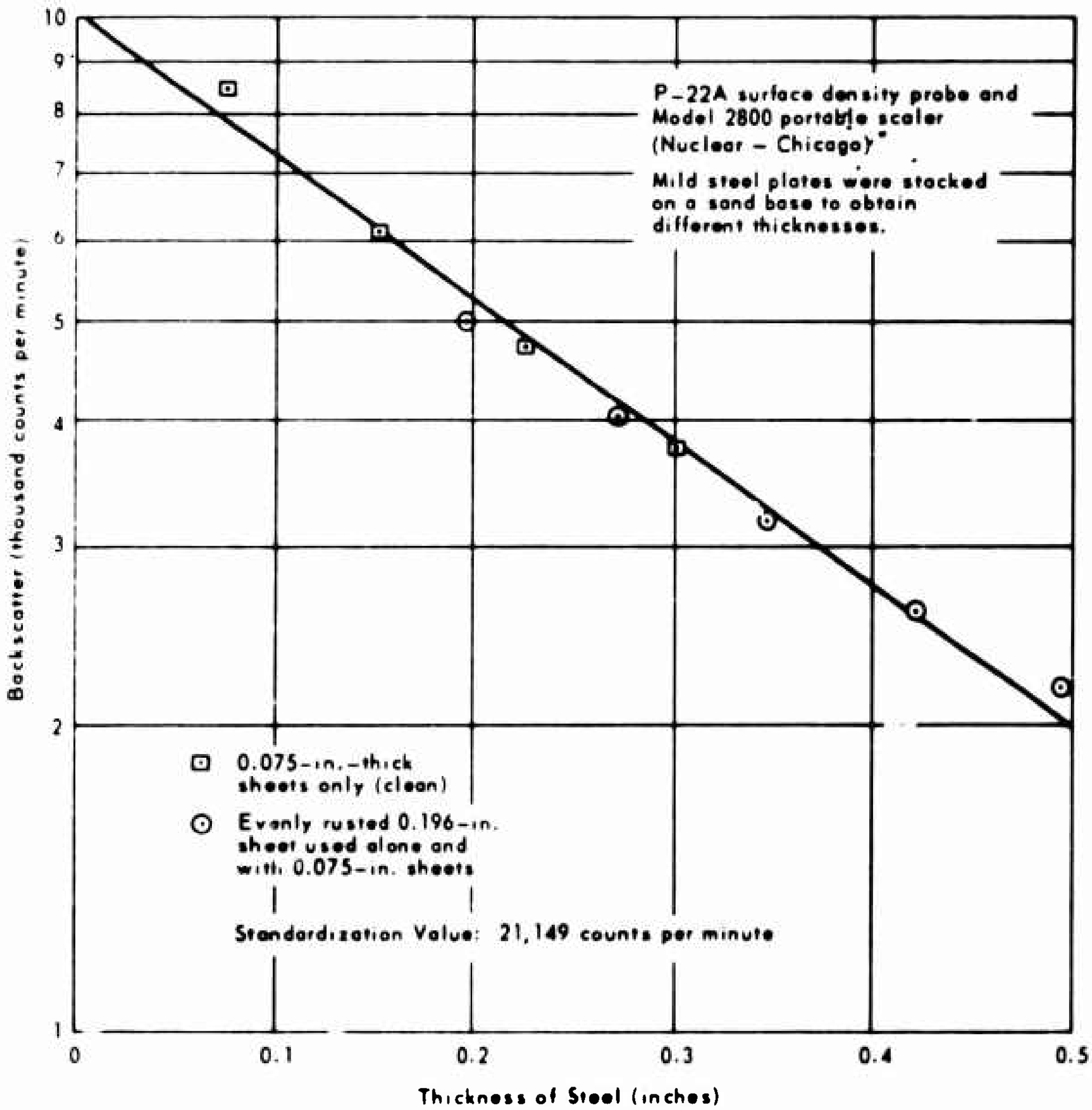

Figure 1. Effect of steel thickness on gamma backscatter.

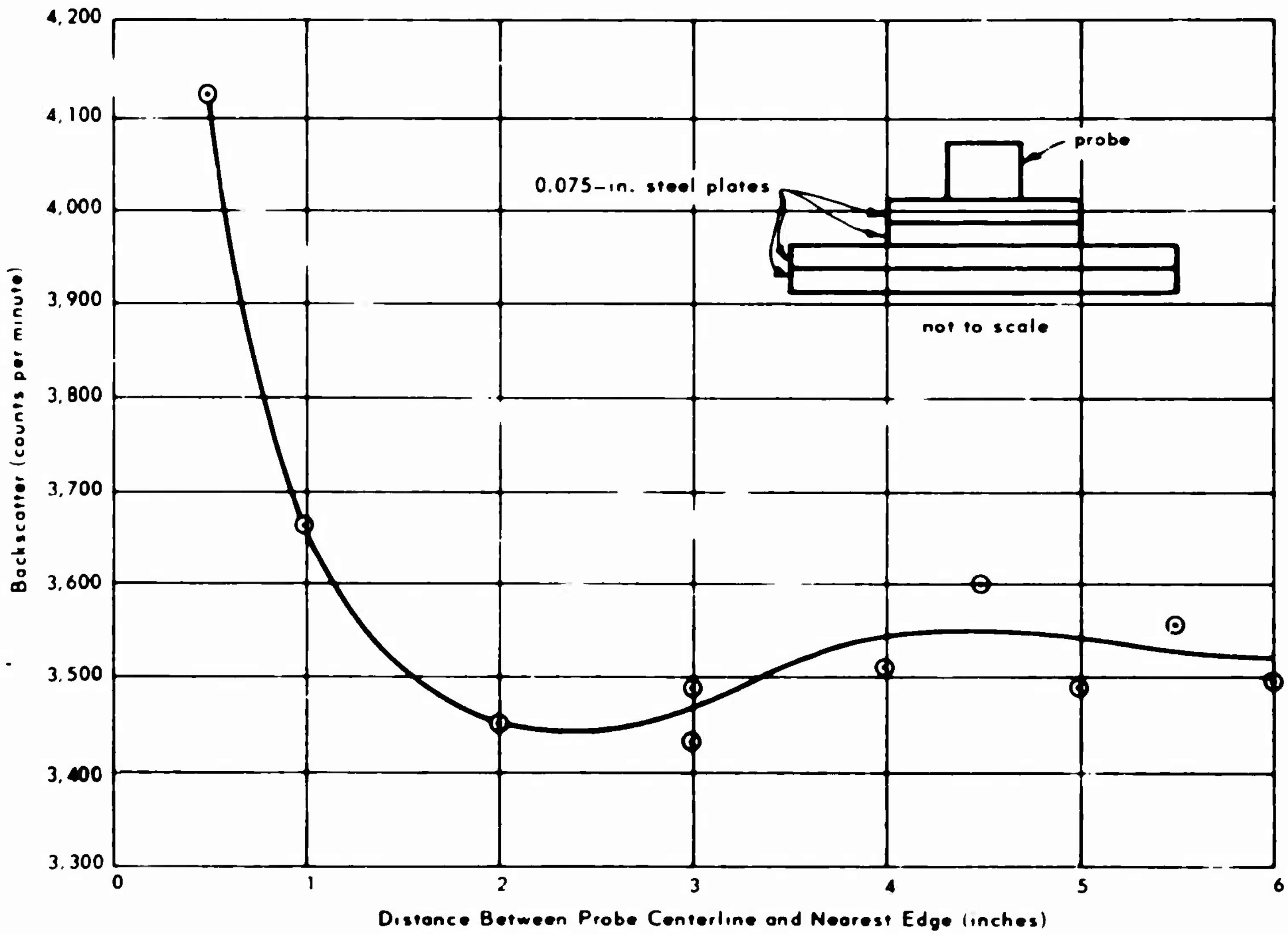

Figure 2. Effect of proximity of probe to edge of simulated pile face.

Table 3. Effect of Rough Surface on Backscatter

Average thickness of metal plate	0.221 inch
Minimum thickness of metal plate	0.215 inch
Maximum thickness of metal plate	0.290 inch
Counts on rough surface of metal plate	5,105 per minute
Estimated thickness of metal plate	0.198 inch
Deviation from average thickness	-10.4 percent
Counts on smooth surface of metal plate	4,579 per minute
Estimated thickness of metal plate	0.2175 inch
Deviation from average thickness	-1.6 percent
Change in estimated thickness induced by air space under probe	0.0195 inch
Change in deviation from average thickness	-8.8 percent

Determining Quality of Concrete

NCEL received an inquiry regarding methods for determining the thickness and density of in-place portland cement concrete. The same surface density probe used to determine the condition as steel sheet piling was used to measure the backscatter from a number of small slabs of concrete. Preliminary results indicated that significant changes took place when different thicknesses of concrete were checked. The scaler-power supply unit malfunctioned and could not be fixed in time to obtain confirming data.

CONCLUSIONS

1. Soil moisture and density gages are acceptable tools for checking earth compaction.

2. Residual steel thickness may be measured by surface density gages.

3. It may be possible to determine the quality of concrete if the effects of thickness and density can be established.

RECOMMENDATIONS

1. Soil moisture and density gages should be authorized for Public Works inspectors, at least at the division level, if work load is sufficient to justify instrument cost.

2. In the inspection of sheet steel piling further work should be authorized to determine the effects produced by roughness, by the presence of air or water between a probe and the steel surface, and by different steel alloys.

3. An investigation should be conducted of backscatter from concrete slabs of different thicknesses and densities.

REFERENCES

1. U. S. Naval Civil Engineering Laboratory. Technical Note N-533: Naval isotope applications, a selected bibliography, by R. H. Seabold and J. Jacovitch. Port Hueneme, Calif., Aug. 1963.

2. Tracerlab Incorporated. Reactor Monitoring Center. Report TLW-1055: A survey and recommendations for radioisotope applications pertinent to the U. S. Naval Civil Engineering Laboratory operations, rev. ed., by L. J. Beaufait, Jr., and J. Kohl. Richmond, Calif., Aug. 1959.

3. U. S. Naval Civil Engineering Laboratory. Technical Note N-606: Recent applications of radioisotopes, by L. B. Gardner. Port Hueneme, Calif., Aug. 1964.

4. U. S. Patent No. 3,084,259: Method of determining pipeline leakage, by W. A. Wilson and G. S. John. Apr. 2, 1963.

5. U. S. Patent No. 3,130,314: Method of using radioactive tracers, by A. Beerbower and J. L. Murray. Apr. 21, 1964.

6. "All that's gold may not glitter," Nucleonics Week, vol. 6, no. 15, Apr. 4, 1965, p. 4.

7. W. Gardner and D. Kirkham. "Determination of soil moisture by neutron scattering," Soil Science, vol. 73, no. 5, May 1952, pp. 391-401.

8. J. R. McHenry. "Theory and application of neutron scattering in the measurement of soil moisture," Soil Science, vol. 95, no. 5, May 1963, pp. 294-307.

9. K. Preiss and K. Newman. "An improved technique for the measurement of density of concrete and soils with gamma radiation," in Fourth International Conference on Non-destructive Testing, Proceedings, held in London 9-13 Sept. 1963. London, Butterworth & Co., 1964.

10. K. Preiss. "Measuring concrete density by gamma ray transmission," Materials Research and Standards, vol. 5, no. 6, June 1965, pp. 285-291.

11. K. Preiss and P. J. Grant. "The optimization of a neutron scattering water content gage for soils or concretes," Journal of Scientific Instruments, vol. 41, no. 9, Sept. 1964, pp. 548-551.

12. "Use of neutron meters in soil moisture measurements." Progress Report of Task Force on Use of Neutron Meters, Committee on Hydrometeorology. American Society of Civil Engineers, Proceedings, Journal of the Hydraulics Division, vol. 90, no. HY6, Nov. 1964, pp. 21-43.

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13 ABSTRACT

The Naval Civil Engineering Laboratory has conducted a study of the potential applications of isotopic devices and techniques within the Naval Shore Establishment. Radiation characteristics, general applications of isotopic devices, and specific problem areas are discussed. Recommendations are included for the use of surface density and moisture gages in the inspection of compacted earth, and for additional work in the determination of the thickness of in-place steel sheet piling and the thickness and density of concrete.

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